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Inelastic Deformation and Strength Degradation in Shocked Geologic Solids

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**6. AUTHOR(S)**

Yogendra M. Gupta and Jow-Lian Ding

**7. PERFORMING ORGANIZATION NAMES(S) AND ADDRESS(ES)**

Washington State University
Institute for Shock Physics
Pullman WA 99164-2816

**8. PERFORMING ORGANIZATION REPORT NUMBER**

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**9. SPONSORING / MONITORING GENCY NAMES(S) AND ADDRESS(ES)**

AFOSR
801 N Randolph St., Rm. 732
Arlington VA 22203-1977

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**13. ABSTRACT (Maximum 200 words)**

Two research tasks were initiated in this project. In the first, preliminary calculations were carried out to examine the response of miniature ruby gauges in metallic targets subject to axisymmetric loading. Although the initial results were encouraging, the calculational effort was discontinued because funding changes by AFOSR did not permit experimental work in this project. In the second task, the development of a damage model was undertaken to describe the shock wave response of a brittle solid. In particular, the focus was on model development to describe both the loading and unloading response in a consistent manner. Preliminary results are encouraging and many features observed in the experimental data are simulated, at least qualitatively, by the model.

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## Objectives and Background

The overall objective of our three-year research program was to examine inelastic deformation and the resulting strength degradation in shocked geologic solids in support of the Air Force shock physics needs in the area of penetrator/target interactions. The original intent was to combine novel experimental developments with appropriate material modeling efforts to gain insight into the nature of the shocked state under planar and non-planar loading.

Because of organizational and programmatic changes at AFOSR, we were informed that our research project was to be cancelled after a one time initial funding. Clearly such a decision by AFOSR was a major disruption to the research project. Continuing with the experimental work did not represent a prudent use of the funds and there is little to show for the effort that was spent in planning and designing planar and 2-D, axisymmetric experiments involving miniature ruby gauges.

As per our communications with the AFOSR personnel, we utilized the remaining funds available for undertaking the development of damage models to describe the response of shocked brittle solids.

## Accomplishments

As indicated above, we spent the project funds on two tasks. Initially, we concentrated on developing experimental designs for using our miniature ruby sensors to examine the target response directly underneath the region of projectile impact. Preliminary calculations utilizing 2-D axisymmetric analyses were undertaken to model some of our earlier experiments that utilized miniature ruby gauges in metallic targets subjected to plate impact loading. The intent of these calculations was to gain insight into relating the optical response of the ruby gauges to the target material response. Because the metallic target (6061 T6 aluminum) response is reasonably well understood, these simulations were viewed as a good starting point for this work. Geologic solids are expected to display considerably more complex response under axisymmetric rod impact conditions. Hence, use of simpler target materials in the initial calculations seemed prudent. Preliminary results on metallic targets were encouraging. However, this effort was discontinued because it was not possible to continue with the experimental effort with the available funds.

Although the AFOSR interest was for geologic solids, we utilized our experimental data on shocked ceramics to aid the development of a damage model for brittle solids. There are many similarities in these two types of materials regarding material strength and inelastic deformation under dynamic loading. For example, they both display considerable strength in compression but are very weak in tension. In particular, we wanted to use our in-situ, unloading data in shocked silicon carbide to develop a consistent description of the material response during loading and unloading.

Our approach to this task was to first carry out a thorough study of the existing models for the impact response of brittle materials, especially the models developed by Adessio and Johnson at Los Alamos National Lab and the Johnson-Holmquist model used in EPIC computer code for penetration simulations. After identifying the strength and weakness of each model in comparison with our experimental data, we then proposed an improved model as described in the following. The model consists of four parts, namely, deviatoric response (strength calculation), volumetric response (pressure calculation), damage evolution, and coupling between damage and stiffness degradation. Since the model is intended for a fully dense ceramic material, we have neglected the volume change associated with inelastic deformation and pore collapse at this point.

The simulations to date show that many aspects of the experimental data on SiC are modeled well using our damage model. However, more work is required to ensure good quantitative agreement with all aspects of the unloading data.

Some of the results obtained in this project will be incorporated into a paper to be presented at APS Topical Conference on Shock Waves in Condensed Matter to be held in Atlanta, Georgia in June 2001.

## Personnel Supported

1. Dr. Jow-Lian Ding, Professor
2. Franklin D. Faultersack, Computational Mechanical Associate
3. Dr. Sunil Dwivedi, Postdoctoral Research Associate